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Carpal tunnel syndrome (CTS) and exposure to vibration, repetitive wrist movements, and heavy manual work: a case-referent study

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ABSTRACT Possible connections between carpal tunnel syndrome (CTS) and exposure to vibrating handheld tools, repetitive wrist movements, and heavy manual work were examined in a case-referent study. The cases were 38 men operated on for CTS between 1974 and 1980. For each case, two referents were drawn from among other surgical cases (hospital referents) and two further referents from the population register and telephone directory, respectively (population referents). Thirty four of 38 cases (89%) and 143 of 152 referents (94%) were interviewed by telephone. An increased prevalence of obesity, rheumatoid disease, diabetes, or thyroid disease was observed among the cases but most did not suffer from any of these disorders. CTS was significantly correlated with exposure to vibration from handheld tools and to repetitive wrist movements but showed a weaker correlation with work producing a heavy load on the wrist. A cause-effect relation between CTS and exposures to handheld vibrating tools and to work causing repetitive movements of the wrist seems probable. Some differences between hospital and population referents indicate that a case-referent study of this type could be biased by inappropriate selection of referents.

An analysis of symptoms among patients examined at the Southern Hospital (Södersjukhuset) in Stockholm between 1974 and 1980 because of suspected vibration injury showed that 10 of 126 patients (7%) had disturbed function of the median nerve distal to the wrist typical of carpal tunnel syndrome (CTS).[1] This observation initiated a case-referent study to examine possible connections between CTS and exposure to vibrating tools, repetitive wrist movements, and heavy manual work. The influence of other factors which could possibly induce CTS such as obesity, rheumatoid arthritis, and some endocrine disorders were also studied.

Material and methods

The cases were men aged 20–66 who were operated on for CTS by division of the carpal ligament at the Sabbatsberg Hospital during 1975–80. CTS was diagnosed clinically by a hand surgeon, and the diagnosis was confirmed electroneurographically by measurement of the conduction velocities in the median nerve at the wrist level. Patients on whom the transverse carpal ligament was divided because of post-traumatic nerve compression were excluded from the study. The remaining 38 patients constituted the cases in this study.

For each case, two referents were drawn from among other surgical cases (hospital referents) and two further referents from the general population register and the telephone directory, respectively (population referents). All referents were matched for sex (only men were included), age (± 3 years), and the hospital referents also for year of operation (± 3 years).

The hospital referents were collected from the medical register at the Southern Hospital. During 1975–80, the catchment areas for the surgical department of this hospital and the clinic of hand surgery of Sabbatsberg Hospital were similar. For each case, one referent had been operated on for gall bladder disease and the other for varicous veins in the legs.

The population referents were living in the catchment area of the clinic of hand surgery of the Sabbatsberg Hospital. A new population referent was drawn if the first could not be interviewed because of death, severe mental retardation, or admission to a

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mental hospital. The age of the telephone subscribers was obtained from the population register.

Both cases and referents were interviewed on the telephone by the same physician using a standard questionnaire. Information was collected on type of work and occupational exposure up to the day of operation of the corresponding case. The interviews dealt with the use of vibrating handheld tools, performance of repetitive wrist movements at work, and work involving heavy load on the wrist. The degree of exposure was evaluated both with regard to the total number of work years and the average number of exposed hours a week. The performance of repetitive wrist movements at work was classified independently by the person interviewed and an occupational hygienist. Exposure to repetitive wrist movements was considered to exist if both agreed and the number of exposure years was defined as the average of their evaluations.

Reference weights were calculated from tables published by Bengtsson *et al*,[2] and obesity was defined as a body weight exceeding the reference weight by more than 10%. Any information about rheumatoid arthritis, diabetes, and thyroid gland disease was noted.

Four of the 38 cases (11%) were not interviewed; one had moved abroad and three had no telephone. The corresponding figures for the hospital referents were seven of 76 (9%); four had no telephone, two had a secret telephone number, and one was not found for unknown reasons. Two of the 76 population referents (3%) were not interviewed; one had moved abroad and one could not be found for unknown reasons.

Chi-squared statistics were used to calculate two sided p values for the differences between cases and referents, odds ratios, and 95% confidence intervals of the odds ratios. The Mantel-Haenszel procedure was used to calculate the total odds ratio and stratification was used to calculate odds ratios for multiple categories.[3]

The study was examined and approved by the ethical committee of the Southern Medical Services District in the County of Stockholm.

Results

There was a significantly higher proportion of subjects with occupational exposure to handheld vibrating tools and repetitive movements of the wrist among the cases than among the referents (table 1). For both types of exposure, the odds ratios tended to increase with increasing exposure time. The proportion of subjects with work causing a great load on the wrist, however, did not differ significantly between cases and referents, although the odds ratios did tend to increase with increasing period of exposure.

The odds ratios for diabetes mellitus, thyroid, and rheumatoid diseases were, throughout, numerically larger than 1, but the numbers were too small to permit statistical analysis of the separate diseases (table 2). The proportion of subjects with at least one of these diseases, however, was significantly higher among the cases than among the referents. The frequency of obese individuals and current smokers did not differ significantly between cases and referents.

The proportion of persons with obesity and occupational exposure to both handheld vibrating tools, repetitive movements of the wrist, and a great load on the wrist was significantly higher among the hospital than among the population referents (table 3). There were, however, no significant differences between the two referent groups for smoking habits or occurrence of diabetes mellitus, thyroid disease, or rheumatoid arthritis.

As may be seen in table 4, the proportion of office workers was lowest among the cases (12%) and highest among the population referents (46%). The unequal distribution of the total material is significant ($p < 0.005$) as are the differences between cases and population referents ($p < 0.001$) and hospital and population referents ($p < 0.005$). The difference between cases and hospital referents, however, is non-significant ($p > 0.10$).

There were significant differences (table 5) between hospital and population referents with regard to some of the variables analysed in table 3. A comparison of the data in tables 1 and 5 shows that the odds ratios for CTS coupled to work with vibrating tools and repetitive movements or great load on the wrists are highest when the referent group is restricted to popula-

Table 1 *Odds ratios of some occupational exposures among 34 cases with CTS by comparison with 143 referents*

Exposure	*Cases*	*No of Referents*	*Odds ratio (95% CI)*	*Two sided p value*
Use of hand held vibrating tools:				
< 1 year	21	120	1·0	—
1–20 years	8	17	2·7 (1·1– 6·7)	0·04
> 20 years	5	6	4·8 (1·5–15·6)	0·01
Mantel-Haenszel estimate	34	143	3·3 (1·6– 6·8)	0·002
Repetitive movements of wrist:				
< 1 year	20	113	1·0	—
1–20 years	5	19	1·5 (0·5– 4·4)	NS
> 20 years	9	11	4·6 (1·8–11·9)	0·002
Mantel-Haenszel estimate	34	143	2·7 (1·3– 5·4)	0·006
Work causing great load on wrist:				
< 1 year	14	80	1·0	—
1–20 years	12	41	1·7 (0·7– 3·9)	NS
> 20 years	8	22	2·1 (0·8– 5·5)	NS
Mantel-Haenszel estimate	34	143	1·8 (0·96–3·5)	NS

Table 2 *Odds ratios of some diseases, obesity, and smoking among 34 cases with CTS by comparison with 143 referents*

Exposure	Cases No	Cases %	Referents No	Referents %	Odds ratio (95% CI)	Two sided p value
Diabetes mellitus	2	6	6	4	1·4	—
Rheumatoid arthritis	4	12	8	6	2·3	—
Thyroid disease	1	3	1	1	4·6	—
Any of the diseases mentioned above	7	21	12	8*	2·8 (1·04–7·6)	0·04
Obesity (> 10% above reference weight)	9	26	22	15*	2·0 (0·8–4·8)	NS
Current smoker	11	32	34	24	1·5 (0·7–3·5)	NS

*Incomplete answer from one referent.

Table 3 *Odds ratios of some occupational exposures, some diseases, obesity, and smoking among 69 hospital referents by comparison with 74 population referents*

Exposure	Referents: Hospital No	Hospital %	Population No	Population %	Odds ratio (95% CI)	Two sided p value
Use of handheld vibrating tools (> 1 year)	16	23	7	9	2·9 (1·1 –7·4)	0·03
Repetitive movements of wrist (> 1 year)	20	29	10	14	2·6 (1·1 –6·0)	0·02
Work causing great load on wrist (> 1 year)	37	54	26	35	2·1 (1·1 –4·2)	0·03
Diabetes mellitus, rheumatoid arthritis, or thyroid disease	7	10	5	7	1·5 (0·5 –5·1)	NS
Obesity (> 10% above reference weight)	15	22	7	9*	2·6 (1·02–6·8)	< 0·05
Current smoker	20	29	14	19	1·7 (0·8 –3·8)	NS

*Incomplete answer from one referent.

Table 4 *Proportion of office workers among cases and referents*

	Office worker: Yes	Office worker: No	Total
Cases	4	30	34
Hospital referents	16	53	69
Population referents	34	40	74

tion referents. Irrespective of duration of exposure, obesity was more common among the cases than among the population referents.

The subjects were stratified with regard to the number of risk factors of significance in this study. The number of subjects having more than two risk factors was too small for separate analysis. As seen in table 6, the odds ratios tend to increase with increasing number of risk factors.

Discussion

CTS is more common among women than men.[4] Women with CTS show an increased prevalence of gynaecological disorders,[5] and CTS may start during

Table 5 *Odds ratios of some occupational exposures and obesity among 34 cases with CTS by comparison with 74 population referents*

Variable	No of: Cases	No of: Referents	Odds ratio (95% CI)	Two sided p value
Use of hand held vibrating tools:				
< 1 year	21	67	1·0	
1–20 years	8	6	4·3 (1·4–12·9)	0·01
> 20 years	5	1	16·0 (2·8–90·2)	0·002
Mantel-Haenszel estimate	34	74	6·1 (2·4–15·0)	< 0·001
Repetitive movements of wrist:				
< 1 year	20	64	1·0	
1–20 years	5	7	2·3 (0·7– 7·9)	NS
> 20 years	9	3	9·6 (2·8–33·0)	< 0·001
Mantel-Haenszel estimate	34	74	4·5 (1·9–10·4)	< 0·001
Work causing great load on wrist:				
< 1 year	14	48	1·0	
1–20 years	12	20	2·1 (0·8– 5·2)	NS
> 20 years	8	6	6·6 (1·4–14·7)	0·01
Mantel-Haenszel estimate	34	74	2·7 (1·3– 5·6)	0·006
Obesity (> 10% above reference weight)	9	7*	3·4 (1·2– 9·8)	0·02

*Incomplete answer from one referent.

Table 6 *Odds ratios correlated with number of risk factors among 34 cases with CTS by comparison with 143 referents*

No of risk factors*	No of subjects: Cases	No of subjects: Referents	Odds ratio (95% CI)	Two-sided p value
Zero	12	85	1·0	
One	8	34	1·7 (0·6– 4·4)	NS
Two	8	17	3·3 (1·2– 9·1)	0·02
>2	6	6	7·1 (2·2–22·7)	<0·001
Mantel-Haenszel estimate	34	142	2·9 (1·6– 5·2)	<0·001

*Each individual can have 0–4 of the following risk factors: vibration exposure > 1 year; repetitive movements of the wrist > 1 year; any of the diseases mentioned in table 2; obesity (> 10% above reference weight).

pregnancy or in the puerperium.[6 7] Rheumatoid arthritis,[8 9] obesity,[10] and endocrine disorders such as diabetes mellitus[11 12] and thyroid disease[13] have been reported to increase the incidence of CTS.

In the present study an increased prevalence of obesity, rheumatoid disease, diabetes, or thyroid disease was found among the cases with CTS. Most, however, did not suffer from any of these disorders, indicating that they are of minor importance in this connection. In vibration exposed groups smoking or taking snuff are linked to an increased risk of developing traumatic vasospastic disease,[14] but the results do not indicate that exposure to nicotine is related to CTS in a similar way.

There is an association between exposure to handheld vibrating tools and the occurrence of CTS,[5 15–18] and a connection between CTS and repetitive hand movements has also been observed in, for example, cleaning workers[19] and butchers.[10] Work with deviated wrists and pinched hand positions is associated with CTS in women with sewing jobs,[4] and positive associations between cumulative trauma disorders (CTS being one of the diagnoses included in this condition) and high force–high repetitive manual jobs have been observed.[20] In a postmortem study histological changes were observed, especially in the most frequently flexed and extended wrist area, suggesting a connection between CTS and repeated exertions with flexed or extended wrists.[21]

The results presented here confirm that exposure to handheld vibrating tools, work causing repetitive movements of the wrist, and possibly also work causing heavy load on the wrist are of importance for the development of CTS. These exposures are often related to each other making it difficult to examine the separate effects in a study such as this. CTS, however, seems to be more closely related to exposure to vibrations from handheld tools and to repetitive wrist movements than to heavy loads on the wrist.

Case-referent studies are sensitive to selection bias causing both false negative and false positive results,[22] but the significance of occupational factors for CTS was seldom taken into consideration during the 1970s, making it unlikely that the cases, which were operated on between 1975 and 1980 were subject to any significant selection bias. Nevertheless, the observed differences between hospital and population referents indicate that a case-referent study of this type could be biased by the inappropriate selection of referents.

Exposure to handheld vibrating tools, and probably also to repetitive movements in the wrist, is more common in blue collar than in white collar professions. Blue collar workers tend to accumulate in inpatient groups as compared with white collar workers,[23] and the differences between cases and referents for such exposures tend to be smaller when the referents are collected from inpatients than when they are collected from the total population. Norell and Ahlbom have found that a study of this type could be affected by selection bias because hospital referents tend to conceal effects due to the exposure under examination.[24] The observed dose response relations and the demonstrated additive effects of different risk factors indicate a cause-effect relation between CTS and exposures to handheld vibrating tools and possibly also to work causing repetitive movements of the wrist.

References

1 Wieslander G, Ekenvall L, Göthe CJ. Vibration induced neurological damage. In: *Proceedings of the international symposium on the protection of workers against vibration, Nis, 1982*. Geneva: International Labour Office, 1982:67–70.

2 Bengtsson C, Hultén B, Larsson B, Noppa H, Steen B, Warnold J. New weight-height tables in Swedish middle aged and elderly men and women. *Lakartidningen* 1981;**98**:3152–4. (In Swedish, summary in English.)

3 Axelsson O. *Epidemiology in occupational and environmental health*. Lund: Studentlitteratur, 1981. (In Swedish.)

4 Armstrong TJ, Chaffin DB. Carpal tunnel syndrome and selected personal attributes. *J Occup Med* 1979;**21**:481–6.

5 Cannon LJ, Bernacki EJ, Walter SD. Personal and occupational factors associated with carpal tunnel syndrome. *J Occup Med* 1981;**23**:255–8.

6 Snell NJC, Coysh HL, Snell BJ. Carpal tunnel syndrome presenting in the puerperium. *Practitioner* 1980;**224**:191–3.

7 Voitk AJ, Mueller JC, Farlinger JE, Johnston RU. Carpal tunnel syndrome in pregnancy. *Can Med Assoc J* 1983;**128**:277–81.

8 Chamberlain MA, Corbett M. Carpal tunnel syndrome in early rheumatoid arthritis. *Ann Rheum Dis* 1970;**29**:149–52.

9 Lang H, Kalliomäki JL, Puusa A, Halonen JP. Sensory neuropathy in rheumatoid arthritis: an electroneurographic study. *Scand J Rheumatol* 1981;**10**:81–4.

10 Falck B, Aarnio P. Left-sided carpal tunnel syndrome in butchers. *Scand J Work Environ Health* 1983;**9**:291–7.

11 Mulder DW, Lambert EH, Bastron JA, Sprague RG. The neuropathies associated with diabetes mellitus. A clinical and electromyographic study of 103 unselected diabetic patients. *Neurology* 1961;**11**:275–84.

12 Phalen GS. The carpal tunnel syndrome. Seventeen years' experience in diagnosis and treatment of six hundred and fifty-four cases. *J Bone Joint Surg* 1966;**48**-A:211–28.

13 Hybbinette CH, Mannerfelt L. The carpal tunnel syndrome. *Lakartidningen* 1974;**71**:3283–5. (In Swedish, summary in English.)
14 Ekenvall L, Lindblad LE. Vibration induced white fingers and nicotine—a preliminary report. *Opuscula Medica Sthlm* 1985; **30**:28–31. (In Swedish, summary in English.)
15 Abbruzzese M, Loeb C, Ratto S, Sacco G. A comparative electrophysiological and histological study of sensory conduction velocity and Meissner corpuscles of the median nerve in pneumatic tool workers. *Eur Neurol* 1977;**16**:106–14.
16 Rothfleish S, Sherman D. Carpal tunnel syndrome. Biomechanical aspects of occupational occurrence and implications regarding surgical management. *Orthopaedics Review* 1978;**7**:107–9.
17 Ahlborg G, Voog L, de Laval J, Glad JH. Carpal tunnel syndrome (II): a case-control study. *Lakartidningen* 1982;**79**:4907–8. (In Swedish.)
18 Chatterjee DS, Barwick DD, Petrie A. Exploratory electromyography in the study of vibration-induced white fingers in rock drillers. *Br J Ind Med* 1982;**39**:89–97.
19 Fati S, Fiorellino G, Nasti G, Ferraro L. Incidence of carpal tunnel syndrome in auxillary hospital workers. *Rivista di Medicina del Lavoro ed Igiene Industriale* 1980;**4**:95–102. (In Italian, summary in English.)
20 Silverstein BA, Fine LJ, Armstrong TJ. Hand wrist cumulative trauma disorders in industry. *Br J Ind Med* 1986;**43**:779–84.
21 Armstrong TJ, Castelli WA, Evans FG, Diaz-Perez R. Some histological changes in carpal tunnel contents and their biomechanical implications. *J Occup Med* 1984;**26**:197–201.
22 Lilienfeld AM, Lilienfeld DE. *Foundations of epidemiology*. 2nd ed. New York: Oxford University Press, 1980.
23 Dahlgren G, Spetz CL. *Facts about illness and its social and occupational distribution in Sweden*. Stockholm: National Swedish Social Welfare Board, 1983. (In Swedish.)
24 Norell SE, Ahlbom A. Hospital versus population referents in two case-referent studies. *Scand J Work Environ Health* 1987;**13**: 62–6.

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3 Weinstein L, Swartz MN. Pathogenic properties of invading micro-organisms. In: Sodeman WA Jr, Sodeman WA, eds. *Pathologic physiology: mechanisms of disease*. Philadelphia: W B Saunders, 1974:457-72.